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(54) **BATTERY MODULE HAVING IMPROVED STRUCTURE FOR FIXING END PLATE AND METHOD OF FIXING THE SAME**

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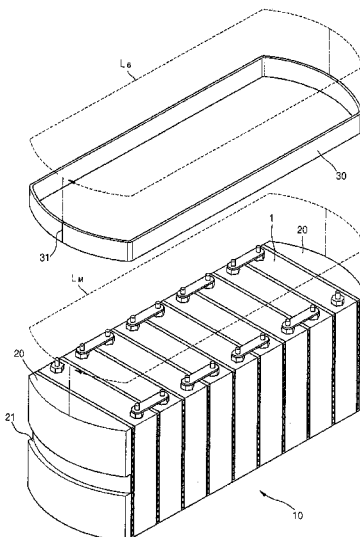
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(57) **ABSTRACT**

A battery module includes a battery unit having a plurality of batteries; a pair of end plates, one of the end plates installed at either end of the battery unit; and a fixing band that encircles the end plates and the battery unit, wherein the fixing band is made from a material that expands when heated and contracts when cooled.

13 Claims, 8 Drawing Sheets



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FIG. 1A

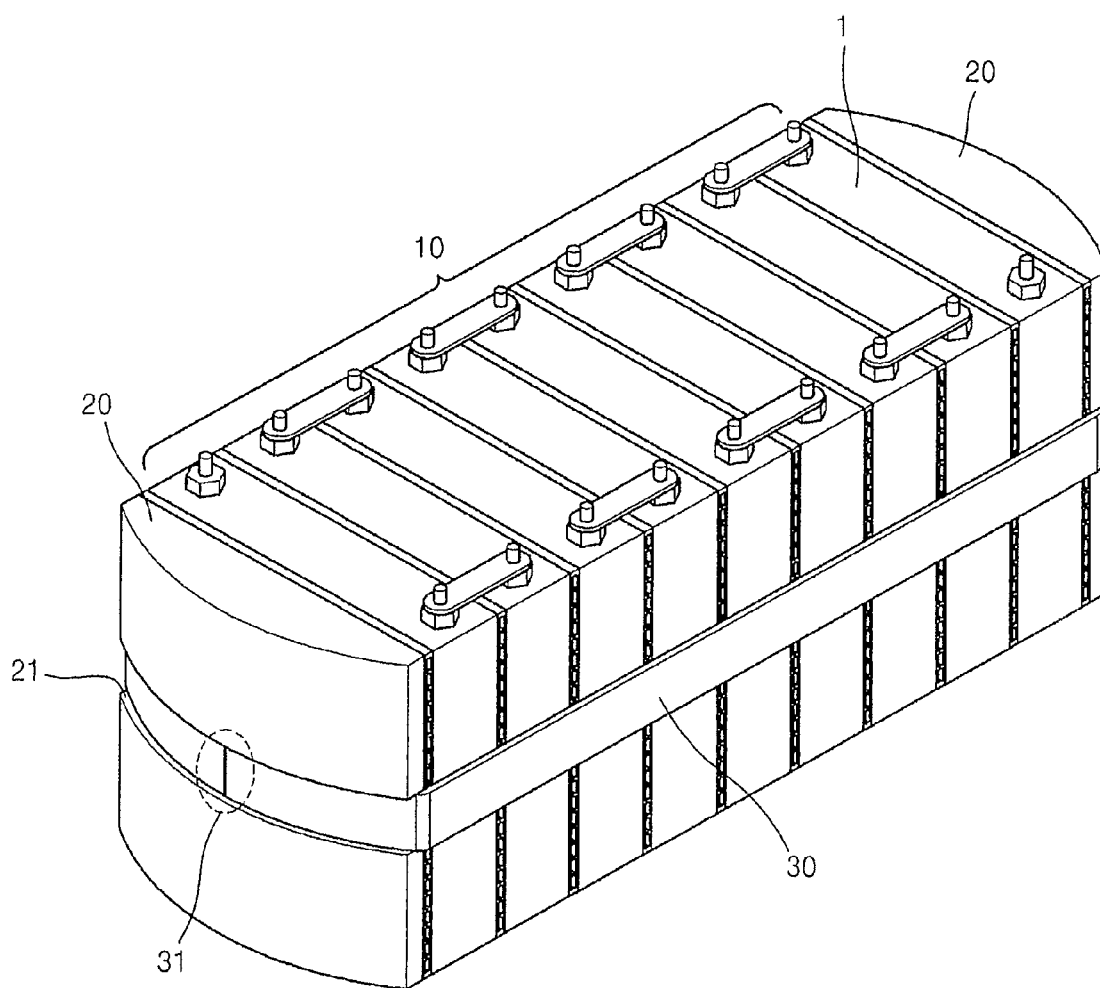


FIG. 1B

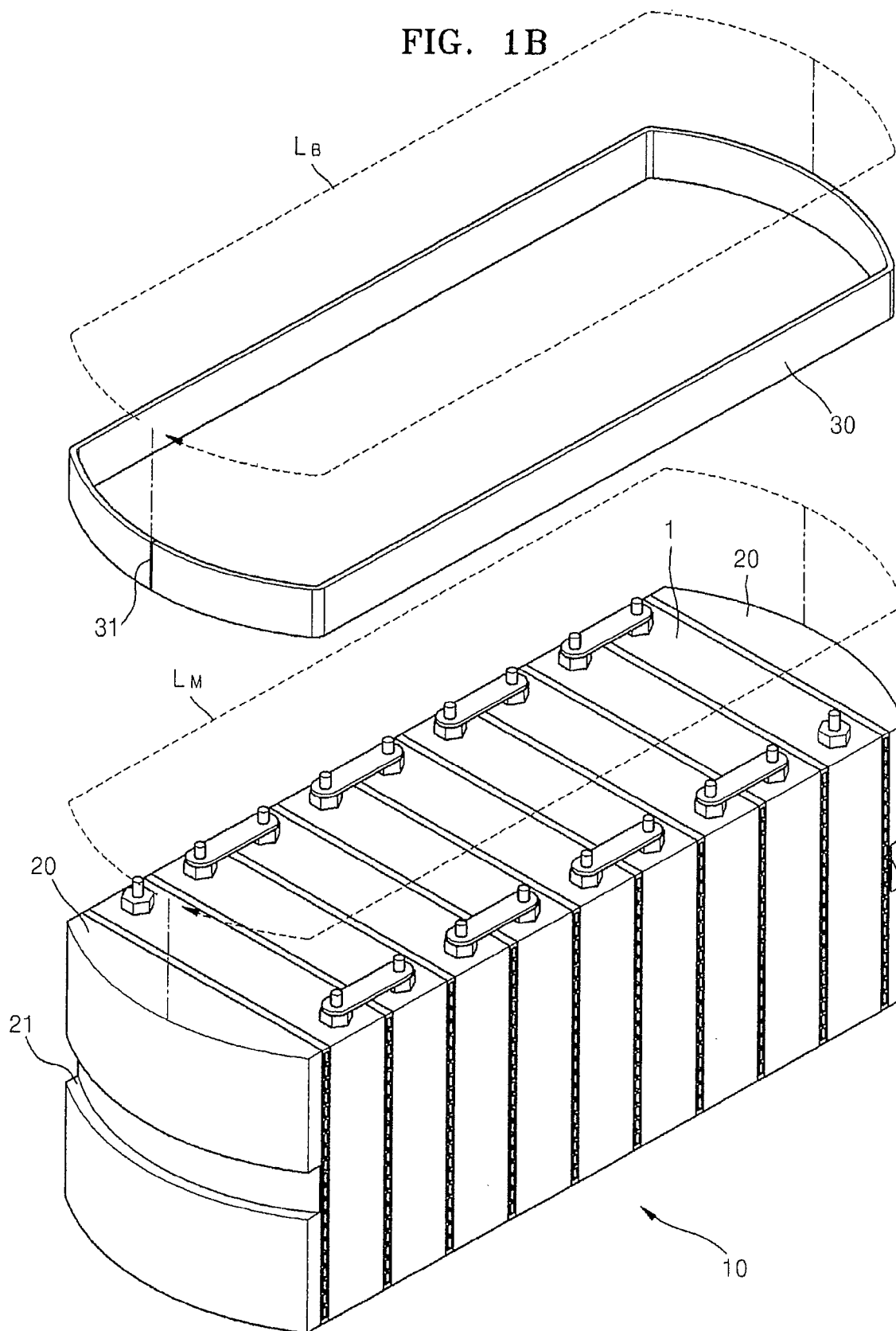


FIG. 2A

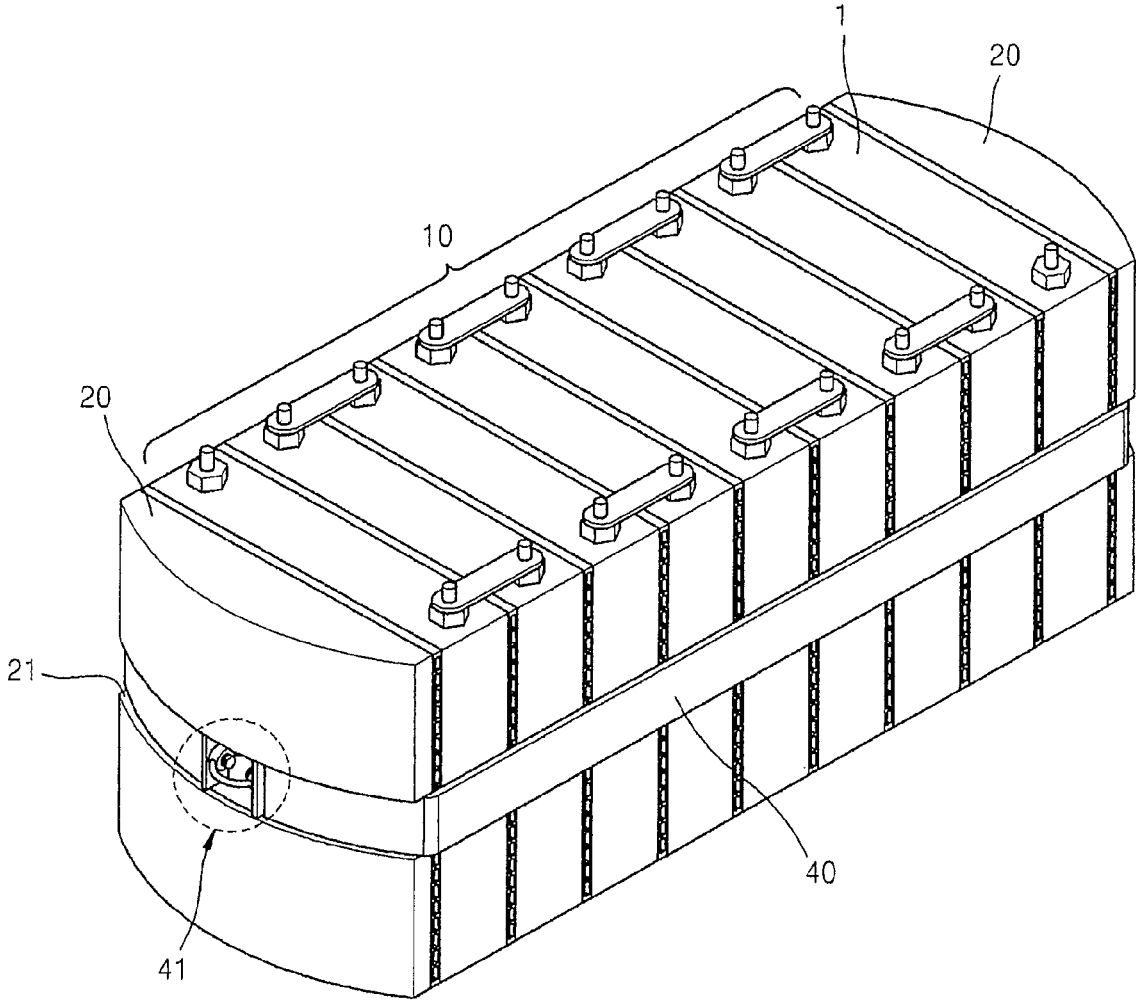


FIG. 2B

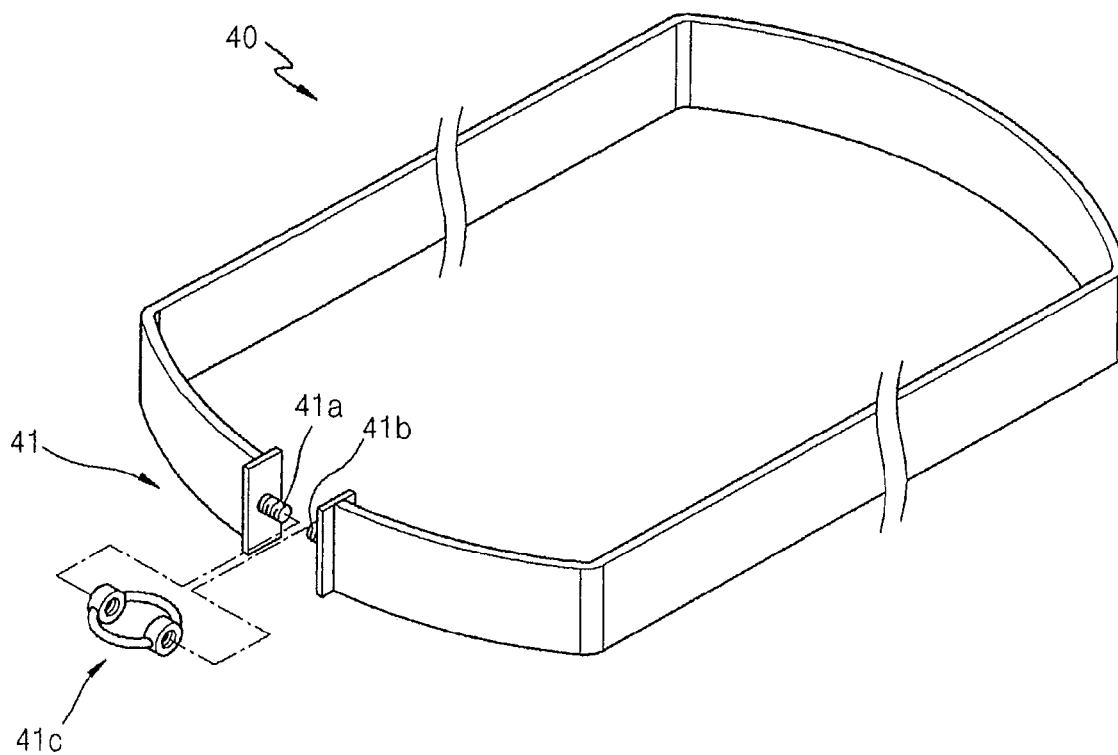


FIG. 3A

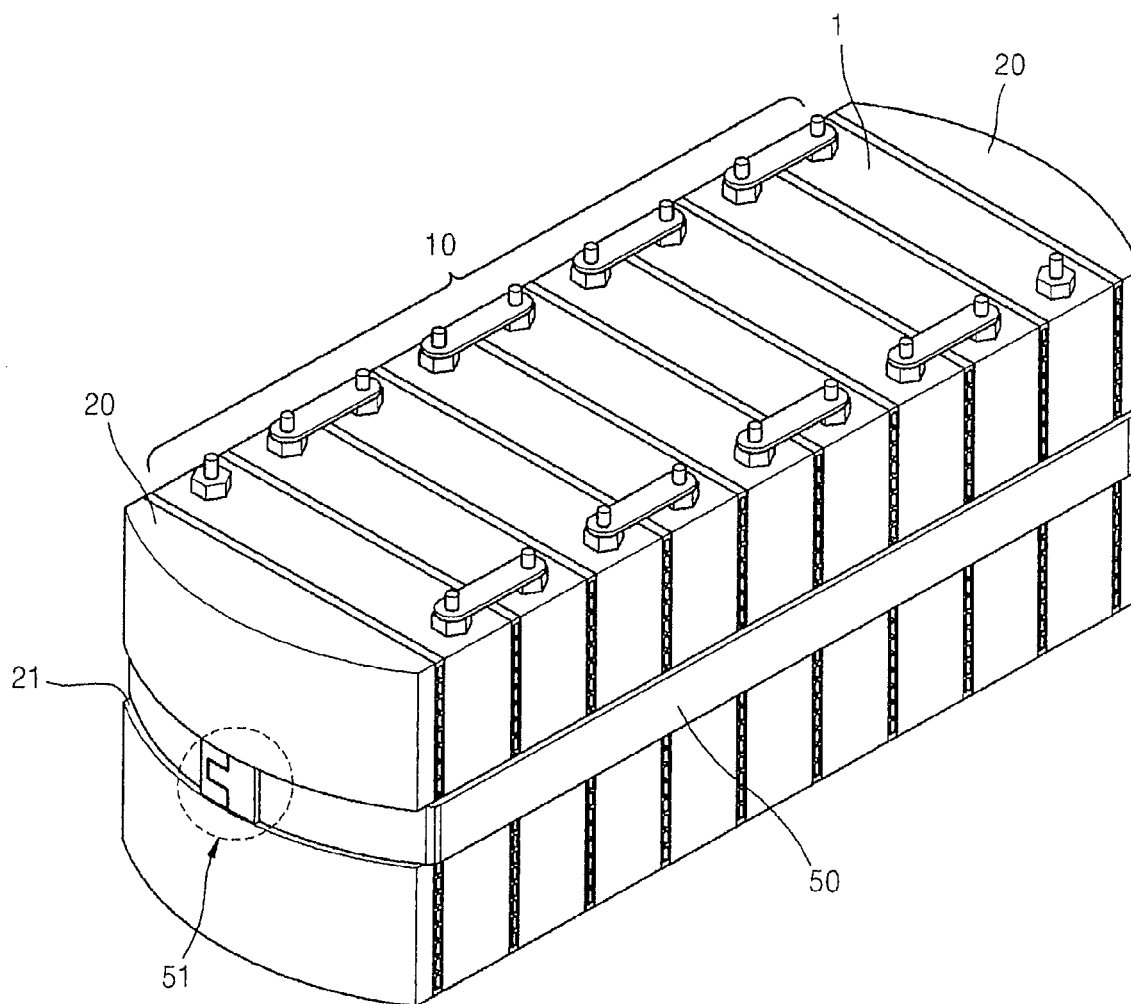


FIG. 3B

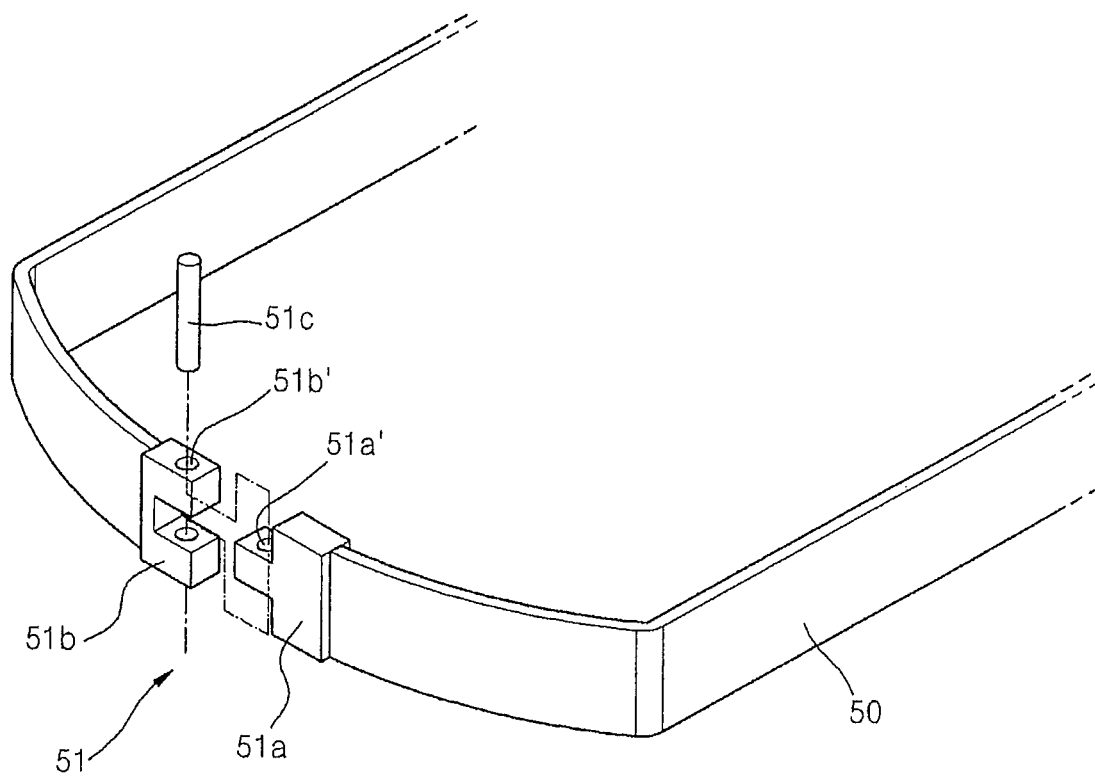


FIG. 4A

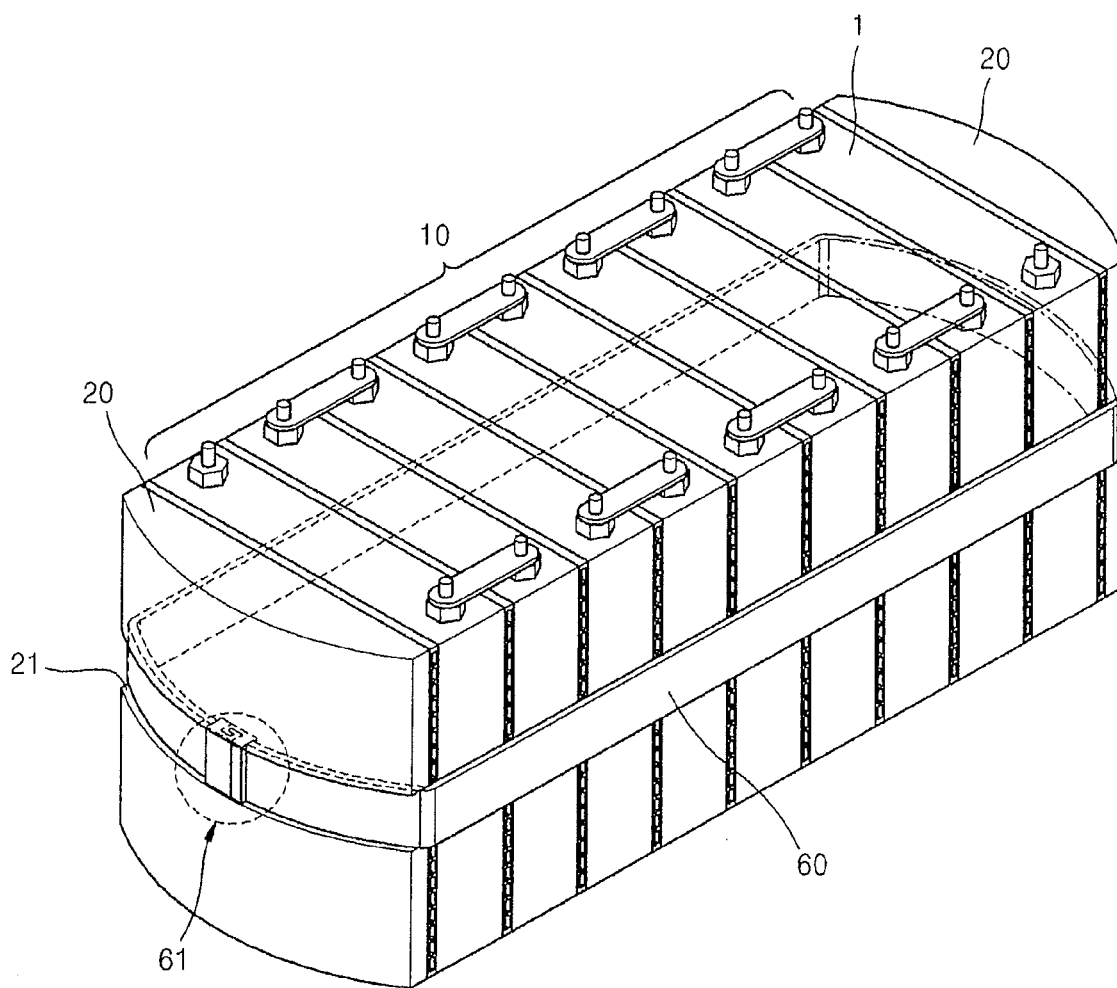
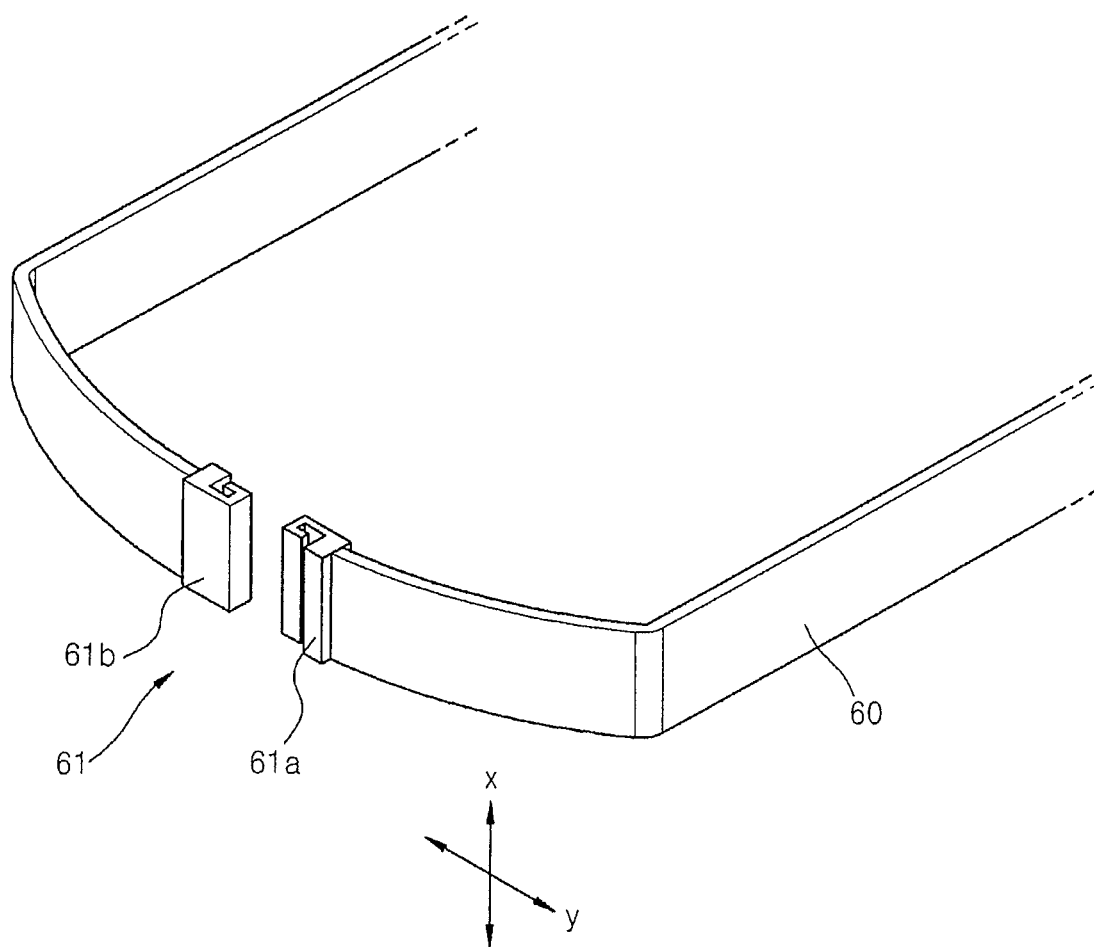


FIG. 4B



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BATTERY MODULE HAVING IMPROVED STRUCTURE FOR FIXING END PLATE AND METHOD OF FIXING THE SAME

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit of Korean Patent Application No. 10-2009-0130022, filed on Dec. 23, 2009, in the Korean Intellectual Property Office, the disclosure of which is incorporated herein in its entirety by reference.

BACKGROUND

1. Field

One or more embodiments of the present invention relate to a battery module having a plurality of batteries connected to each other.

2. Description of the Related Art

A battery module is an element of a high-capacity power supply unit formed of a plurality of batteries connected to each other and may be used as a power source for, for example, electric vehicles.

The batteries forming such a battery module are often lithium ion batteries. In a lithium ion battery, the performance thereof does not often deteriorate even if charging and discharging is repeatedly performed. However, a negative electrode of the battery may expand while lithium ions are transferred during charging. Since the battery module is formed of a plurality of lithium ion batteries connected to each other in series or in parallel, if each lithium ion battery expands a little, the entire battery module may be expanded by about 5% to about 10%. As such, the form or shape of the battery module may be excessively modified or distorted so that attaching and separating of the battery module to and from its original position may be difficult, causing electric resistance of the batteries to increase. Moreover, if the battery module is used in electric vehicles, about eight battery modules are stacked to form a battery pack to be installed in the electric vehicles. Thus, if the form of each battery module is modified, the degree of modification over the entire battery module assembly is great and thus serious problems may occur.

Accordingly, in the battery module, end plates are placed at both ends of secondary battery lines in order to suppress expansion of the secondary batteries and bar type connection rods are connected to the end plates placed at both ends of secondary battery lines, thereby fixing the end plates.

However, in general, since the connection rods and the end plates are connected to each other by using a number of bolts and nuts, it takes a relatively long time to connect them and the bolts and nuts protrude from of the battery module, thereby increasing the volume of the battery module.

An increase in the volume of the battery module causes an overall volume increase in devices employing the battery module and thus limits design of the devices. In particular, if the battery module is employed in electric vehicles, an installation space is limited and thus, if the volume of the battery module is reduced, more design flexibility is permitted.

SUMMARY

One or more embodiments of the present invention include a battery module having an improved structure for fixing end plates without using bolts and nuts.

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According to one or more embodiments of the present invention, a battery module includes a battery unit having a plurality of batteries; a pair of end plates, one of the end plates installed at either end of the battery unit; and a fixing band that encircles the end plates and the battery unit, wherein the fixing band is made from a material that expands when heated and contracts when cooled.

In one embodiment, the fixing band includes a fastener for connecting ends of the fixing band together to form a closed-loop. For example, the fastener may be a weld. In alternate embodiments, the fastener may include male threaded parts being threaded in opposite directions and a turnbuckle combined with the male threaded parts, wherein the fastener is between ends of the fixing band; a tongue and a groove that fit to each other and a pin that is inserted through openings in the tongue and groove, wherein the fastener is between ends of the fixing band; or a clip at each end of the fixing band, wherein the clips are slidably engaged.

In one embodiment, an outwardly facing surface of the end plates is formed in an arc form protruding away from the battery unit and the end plate has an accommodation groove in which the fixing band is accommodated. Further, the fixing band may be made of a material such that a length of the fixing band can be lengthened by heating and can be shortened by cooling, for example, an aluminum-coated steel sheet or a galvanized steel sheet.

Also provided is a method of assembling a battery module including a plurality of batteries and a pair of end plates, one of the end plates installed at either end of the battery unit, the method including thermally extending a length of a fixing band so that the length of the fixing band is longer than a circumference of an assembly of the battery unit and the end plates; installing the fixing band around the assembly; and cooling the fixing band to shorten the length of the fixing band such that the fixing band contacts each of the end plates.

In one embodiment, the fixing band is thermally expanded by high-frequency heating and is cooled by natural cooling or forced ventilation cooling. Additionally, the ends of the fixing band may be attached together using any one of the fasteners described or by any other suitable fastener.

BRIEF DESCRIPTION OF THE DRAWINGS

These and/or other aspects will become apparent and more readily appreciated from the following description of the embodiments, taken in conjunction with the accompanying drawings of which:

FIG. 1A is a diagram of a battery module according to an embodiment of the present invention;

FIG. 1B is a diagram of a fixing band of the battery module of FIG. 1A;

FIG. 2A is a diagram of a battery module according to another embodiment of the present invention;

FIG. 2B is a diagram of a fixing band of the battery module of FIG. 2A;

FIG. 3A is a diagram of a battery module according to still another embodiment of the present invention;

FIG. 3B is a diagram of a fixing band of the battery module of FIG. 3A;

FIG. 4A is a diagram of a battery module according to yet another embodiment of the present invention; and

FIG. 4B is a diagram of a fixing band of the battery module of FIG. 4A.

DETAILED DESCRIPTION

FIGS. 1A and 1B illustrate a battery module according to an embodiment of the present invention. As illustrated in

FIG. 1A, the battery module according to the present embodiment includes a battery unit 10 and a pair of end plates 20, wherein the battery unit 10 includes a plurality of batteries 1 connected to each other in line and one of the pair of end plates 20 is installed at either end of the battery unit 10. A fixing band 30 surrounds and tightly binds an assembly of the pair of end plates 20 and the battery unit 10 and thus opposes the expansion of the battery unit 10. That is, if the battery unit 10 expands, a force pushing the pair of end plates 20 to the outside (i.e., away from each other) is exerted. Here, the fixing band 30 secures the pair of end plates 20 so they are not significantly moved away from each other, and thus a significant modification or distortion of the battery module is suppressed.

The fixing band 30 is formed of a material that expands while heated at high frequencies and contracts while cooled down. Examples of the material may include an aluminum-coated steel sheet or a galvanized steel sheet used in an explosion protection band of a Braun tube. The material may be a composition containing iron (Fe) as a base, carbon (C) of about 0.005 wt % or below, nitrogen (N) of about 0.005 wt % or below, silicon (Si) of about 0.1 to 0.5 wt %, phosphorus (P) of about 0.1 wt % or below, sulfur (S) of about 0.02 wt % or below, manganese (Mn) of about 1.05 to about 2.0 wt %, and aluminum (Al) of about 1.0 wt % or below. The length L_B (refer to FIG. 1B) of the fixing band 30 at room temperature is equal to or shorter than the total circumference L_M (refer to FIG. 1B) of the assembly of the battery unit 10 and the end plates 20; however, the length of the fixing band L_B is lengthened by an amount $L_{\text{expansion}}$ over the total circumference L_M of the assembly of the battery unit 10 and the end plates 20 by heating. That is, $L_B + L_{\text{expansion}} \geq L_M > L_B$ and the fixing band 30 is manufactured to satisfy such a condition.

A combining unit 31 or fastener connects both ends of the fixing band 30. In the present embodiment, the combining unit 31 is a weld formed by welding. That is, ends of the fixing band 30 are attached together by welding without using a separate connection member so as to form a closed-loop form. The welding may be butt welding or lap welding. However, the welding method is not limited as long as the weld is sufficient to ensure that the ends do not separate due to the expansion of the battery unit 10.

The end plates 20 are formed in an arc form having a convex center so that an angle of a bend that occurs while the fixing band 30 winds around the end plates 20 is eased and thus the fixing band 30 is less likely to be damaged. An accommodation groove 21 is the groove for accommodating the fixing band 30 and holds the installation position of the fixing band 30.

Fixing of the assembly of the battery unit 10 and the end plates 20 by using the fixing band 30 may be performed as follows.

First, the fixing band 30, which may be expanded by heating and contracted by cooling, is prepared. The fixing band 30 is manufactured to satisfy the condition, $L_B + L_{\text{expansion}} \geq L_M > L_B$, and both ends of the fixing band 30 are bound by welding, thereby forming a closed-loop.

The fixing band 30 is heated at high frequencies and expands causing the length thereof to be longer than the circumference of the assembly of the battery unit 10 and the end plates 20, that is, $L_B \rightarrow L_B + L_{\text{expansion}}$.

The expanded fixing band 30 is fixed in the accommodation groove 21 and is installed around the assembly of the battery unit 10 and the end plates 20.

Then, the fixing band 30 is cooled and contracted so that the length thereof returns to substantially its original length,

that is, $L_B + L_{\text{expansion}} \rightarrow L_B$. Since the original length L_B of the fixing band 30 is equal to or shorter than the circumference L_M of the assembly of the battery unit 10 and the end plates 20, a strong clamping force is exerted. Accordingly, if the battery unit 10 expands, the fixing band 30 firmly supports the pair of end plates 20 so that there is no gap therebetween. The fixing band 30 may be cooled by natural cooling by remaining at room temperature or may be cooled by forced ventilation.

Accordingly, if the battery unit 10 and the end plates 20 are fixed using the fixing band 30 which may expand and contract, the connection unit minimally protrudes from the fixing band compared to if bolts and nuts are used and also eliminates bolts from having to be connected by nuts. Thus, an assembling process is convenient and a structure is simple.

FIGS. 2A and 2B illustrate a battery module according to another embodiment of the present invention.

As illustrated in FIG. 2A, the battery module according to the present embodiment includes the battery unit 10 including the plurality of batteries 1 connected to each other in line, the pair of end plates 20, one end plate installed at either end of the battery unit 10, and a fixing band 40 that surrounds and tightly binds an assembly of the pair of end plates 20 and the battery unit 10.

The fixing band 40 is formed of a material that expands while heated at high frequencies and contracts while cooled down. Examples of the material may include an aluminum-coated steel sheet or a galvanized steel sheet used in an explosion protection band of a Braun tube.

The length L_B of the fixing band 40 is equal to or shorter than the total circumference L_M of the assembly of the battery unit 10 and the end plates 20 at room temperature; however, the length L_B of the fixing band is lengthened over the total circumference L_M of the assembly of the battery unit 10 and the end plates 20 by an amount $L_{\text{expansion}}$ added to the length L_B based on the expansion during heating of the fixing band 40. That is, $L_B + L_{\text{expansion}} \geq L_M > L_B$ and the fixing band 40 is manufactured to satisfy such a condition.

A combining unit or fastener 41 connects both ends of the fixing band 40. In the present embodiment, the combining unit 41 includes a turnbuckle 41c and threaded screw parts 41a and 41b. Referring to FIG. 2B, the screw parts 41a and 41b are formed at ends of the fixing band 40 and include screws facing each other and threaded in different directions. That is, if the screw part 41a at one side is a right screw (i.e., threaded clockwise), the screw part 41b at the other side is a left screw (i.e., threaded counterclockwise). The turnbuckle 41c includes a female threaded screw portion to fit each of the screw parts 41a and 41b. Accordingly, if the turnbuckle 41c turns in one direction, the screw parts 41a and 41b are simultaneously combined by and coupled to the turnbuckle 41c.

The turnbuckle 41c is located in the accommodation groove 21 prepared in the end plate 20 and thus does not significantly protrude from the assembly.

Fixing of the assembly of the battery unit 10 and the end plates 20 by using the fixing band 40 may be performed as follows.

First, the fixing band 40, which may be expanded by heating and contracted by cooling, is prepared. Ends of the fixing band 40 are combined by the turnbuckle 41c and the screw parts 41a and 41b, thereby forming a closed-loop form. When the fixing band 40 is combined in a closed-loop form, the fixing band 40 is manufactured to satisfy the condition, $L_B + L_{\text{expansion}} \geq L_M > L_B$.

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The fixing band **40** is heated at high frequencies and expands so that the length thereof is longer than the circumference of the assembly of the battery unit **10** and the end plates **20**, that is, $L_B \rightarrow L_B + L_{\text{expansion}}$.

The expanded fixing band **40** is fixed in the accommodation groove **21** to fit the turnbuckle **41c** and is installed around the assembly of the battery unit **10** and the end plates **20**.

Then, the fixing band **40** is cooled and contracted so that the length thereof returns to substantially its original length, that is, $L_B + L_{\text{expansion}} \rightarrow L_B$. Since the original length L_B of the fixing band **40** is equal to or shorter than the circumference L_M of the assembly of the battery unit **10** and the end plates **20**, a strong clamping force is exerted. Accordingly, if the battery unit **10** is expanded, the fixing band **40** firmly supports the pair of end plates **20** so that there is no gap therebetween.

FIGS. **3A** and **3B** illustrate a battery module according to another embodiment of the present invention.

As illustrated in FIG. **3A**, the battery module according to the present embodiment includes the battery unit **10** including the plurality of batteries **1** connected to each other in line, the pair of end plates **20**, one end plate installed at either end of the battery unit **10**, and a fixing band **50** that surrounds and tightly binds an assembly of the pair of end plates **20** and the battery unit **10**.

The fixing band **50** is formed of a material that expands when heated at high frequencies and contracts when cooled down. Examples of the material may include an aluminum-coated steel sheet or a galvanized steel sheet used in an explosion protection band of a Braun tube.

The length L_B of the fixing band **50** is equal to or shorter than the total circumference L_M of the assembly of the battery unit **10** and the end plates **20** at room temperature; however, the length of the fixing band L_B is lengthened to be greater than the total circumference L_M of the assembly of the battery unit **10** and the end plates **20** by the amount $L_{\text{expansion}}$ by heating. That is, $L_B + L_{\text{expansion}} \geq L_M > L_B$ and the fixing band **50** is manufactured to satisfy such a condition.

A combining unit or fastener **51** connects both ends of the fixing band **50**. In the present embodiment, the combining unit **51** includes prominence and depression (i.e., a tongue and a groove) parts **51a** and **51b** and a combining pin **51c**. Referring to FIG. **3B**, the tongue and groove parts **51a** and **51b**, which fit to each other, are formed at ends of the fixing band **50**, the tongue **51a** being on one end and the groove **51b** being on the other end. The tongue and groove parts **51a** and **51b** respectively include openings **51a'** and **51b'** penetrating therethrough. Accordingly, the tongue and groove parts **51a** and **51b** are fit to each other and the combining pin **51c** is inserted through the openings **51a'** and **51b'**, thus, fixing both ends of the fixing band **50** together.

Fixing of the assembly of the battery unit **10** and the end plates **20** by using the fixing band **50** may be performed as follows.

First, the fixing band **50**, which may be expanded by heating and contracted by cooling, is prepared. Both ends of the fixing band **50** are combined by the tongue and groove parts **51a** and **51b** and the combining pin **51c**, thereby forming a closed-loop. After the fixing band **50** is combined in a closed-loop form, the fixing band **50** is manufactured to satisfy the condition, $L_B + L_{\text{expansion}} \geq L_M > L_B$.

The fixing band **50** is heated at high frequencies and expands so that the length thereof is longer than the circumference of the assembly of the battery unit **10** and the end plates **20**, that is, $L_B \rightarrow L_B + L_{\text{expansion}}$.

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The expanded fixing band **50** is fixed in the accommodation groove **21** and is installed around the assembly of the battery unit **10** and the end plates **20**.

Then, the fixing band **50** is cooled and contracted so that the length thereof returns to substantially its original length, that is, $L_B + L_{\text{expansion}} \rightarrow L_B$. Since the original length L_B of the fixing band **50** is equal to or shorter than the circumference L_M of the assembly of the battery unit **10** and the end plates **20**, a strong clamping force is exerted. Accordingly, if the battery unit **10** is expanded, the fixing band **50** firmly supports the pair of end plates **20** so that there is no gap therebetween.

FIGS. **4A** and **4B** illustrate a battery module according to another embodiment of the present invention.

As illustrated in FIG. **4A**, the battery module according to the present embodiment includes the battery unit **10** including the plurality of batteries **1** connected to each other in line, the pair of end plates **20**, one end plate installed at either end of the battery unit **10**, and a fixing band **60** that surrounds and tightly binds an assembly of the pair of end plates **20** and the battery unit **10**.

The fixing band **60** is formed of a material that expands when heated at high frequencies and contracts when cooled down. Examples of the material may include an aluminum-coated steel sheet or a galvanized steel sheet used in an explosion protection band of a Braun tube.

The length L_B of the fixing band **60** is equal to or shorter than the total circumference L_M of the assembly of the battery unit **10** and the end plates **20** at room temperature; however, the length of the fixing band L_B is lengthened to be greater than the total circumference L_M of the assembly of the battery unit **10** and the end plates **20** by the amount $L_{\text{expansion}}$ by heating. That is, $L_B + L_{\text{expansion}} \geq L_M > L_B$ and the fixing band **60** is manufactured to satisfy such a condition.

A combining unit or fastener **61** connects both ends of the fixing band **60** together. In the present embodiment, the combining unit **61** includes clips **61a** and **61b**. Referring to FIG. **4B**, the clips **61a** and **61b** slide together to be fastened to each other and are formed at ends of the fixing band **60**. Accordingly, if the clips **61a** and **61b** are combined with each other, the clips **61a** and **61b** are not separable from each other in a tensile direction (a Y-axis direction, see FIG. **4B**) which is substantially perpendicular to a sliding direction (an X-axis direction).

Fixing of the assembly of the battery unit **10** and the end plates **20** by using the fixing band **60** may be performed as follows.

First, the fixing band **60**, which may be expanded by heating and contracted by cooling, is prepared. Both ends of the fixing band **60** are combined by the clips **61a** and **61b**, thereby forming a closed-loop. While the fixing band **60** is combined in a closed-loop form, the fixing band **60** is manufactured to satisfy the condition, $L_B + L_{\text{expansion}} \geq L_M > L_B$.

The fixing band **60** is heated at high frequencies and expands so that the length thereof is longer than the circumference of the assembly of the battery unit **10** and the end plates **20**, that is, $L_B \rightarrow L_B + L_{\text{expansion}}$.

The expanded fixing band **60** is fixed in the accommodation groove **21** and is installed around the assembly of the battery unit **10** and the end plates **20**.

Then, the fixing band **60** is cooled and contracted so that the length thereof returns to substantially its original length, that is, $L_B + L_{\text{expansion}} \rightarrow L_B$. Since the original length L_B of the fixing band **60** is equal to or shorter than the circumference L_M of the assembly of the battery unit **10** and the end plates **20**, a strong clamping force is exerted. Accordingly, if

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the battery unit **10** is expanded, the fixing band **60** firmly supports the pair of end plates **20** so that there is no gap therebetween.

As described above, according to one or more of the above embodiments of the present invention, the fixing band that is expanded by being heated and is contracted by being cooled in the battery module applies a restoring or biasing force to the end plates in a direction opposite to battery expansion. Thus, assembling of the battery module is simpler than a general battery module to which a number of bolts and nuts are connected. Also, no parts of bolts and nuts protrude outside and thus the volume of the battery module may be reduced.

It should be understood that the exemplary embodiments described herein should be considered in a descriptive sense only and not for purposes of limitation. Descriptions of features or aspects within each embodiment should typically be considered as available for other similar features or aspects in other embodiments.

What is claimed is:

1. A battery module comprising:
a battery unit comprising a plurality of batteries;
a pair of end plates, one of the end plates installed at either end of the battery unit, wherein each of the end plates has an accommodation groove extending in a first direction and an end face, wherein the end face and the accommodation groove are formed entirely in an arc protruding away from the battery unit; and
a fixing band oriented in and continuously contacting the accommodation groove in the first direction so as to encircle the end plates and the battery unit, the fixing band having a first end and a second end and being entirely continuous, wherein the first end and the second end abut each other, and wherein the fixing band comprises a material that expands when heated and contracts when cooled.
2. The battery module of claim 1, wherein the fixing band comprises a fastener connecting ends of the fixing band together to form a closed-loop.
3. The battery module of claim 2, wherein the fastener is a weld.
4. The battery module of claim 1, wherein the fixing band comprises a material such that a length of the fixing band can be lengthened by heating so that the length of the fixing band

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is longer than a circumference of an assembly of the battery unit and the end plates and such that the length of the fixing band can be shortened by cooling such that the fixing band contacts each of the end plates.

5. The battery module of claim 1, wherein the fixing band comprises aluminum-coated steel or galvanized steel.

6. A method of assembling a battery module comprising a plurality of batteries and a pair of end plates, one of the end plates installed at either end of the battery unit, the method comprising:

thermally extending a length of a fixing band so that the length of the fixing band is longer than a circumference of an assembly of the battery unit and the end plates;
installing the fixing band around the assembly; and
cooling the fixing band to shorten the length of the fixing band such that the fixing band contacts each of the end plates.

7. The method of claim 6, wherein the fixing band is thermally expanded by high-frequency heating.

8. The method of claim 6, wherein the fixing band is cooled by natural cooling or forced ventilation cooling.

9. The method of claim 6, further comprising attaching ends of the fixing band together to form a closed loop.

10. The method of claim 9, wherein the ends of the fixing band are attached by welding.

11. The method of claim 9, wherein the ends of the fixing bands include male threaded parts being threaded in opposite directions and a turnbuckle and wherein the ends of the fixing band are attached by threading the turnbuckle onto the male threaded parts.

12. The method of claim 9, wherein a first end of the ends has a tongue with an opening extending therethrough and a second end of the ends has a groove with an opening extending therethrough, wherein the ends are attached by inserting the tongue into the groove portion and inserting a pin into the openings in the tongue and the groove.

13. The method of claim 9, wherein the ends of the fixing band each include a clip and wherein the ends are attached to each other by sliding the clip from a first end of the ends into the clip of a second end of the ends.

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